INDIAN TEA ASSOCIATION

TOCKLAI EXPERIMENTAL STATION

MEMORANDUM No. 8

NOTES ON ROOT DISEASES OF TEA

IN NORTH EAST INDIA

BY

A. C. TUNSTALL

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Dated, 24th January 1940

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CHAPTER 1.

INTRODUCTION.

A comprehensive description of all the root diseases obtained on tea in North East India is not attempted in this memorandum. Its main object is to help planters to distinguish root diseases caused directly by a parasitic fungus from those in which the parasite is secondary. Only two of each type are described in detail. These serve to emphasize the difference in treatment required. Purely technical details have been relegated to the mycological notes. In these, brief references to the other root diseases observed on tea in North East India are included. In the key given below only those diseases which have very definite macroscopic characteristics are referred to.

In Watt & Mann's classical work "The Pests and Blights of the Tea Plant", 2nd Edition, published in 1903, only two root diseases are mentioned. These were named Stump Rot and Internal Root Rot. These diseases were named by Messrs. Massee and Butler but the description of Stump Rot probably refers to a number of diseases and not to the *Rosellinia* sp., of which specimens had been sent for identification. Actually *Rosellinia* sp., is comparatively rare on tea in North East India. If highly trained and accurate observers such as Watt and Mann failed to realise that the specimens sent for identification were not representative it is hardly surprising that planters not infrequently fail in this respect. Some suggestions on how to select and send specimens for accurate diagnosis are therefore included.

Most of the common root diseases of tea are also found on rubber and many of them were first identified on rubber in Ceylon, Java and Malaya. None of the fungi observed to be associated with tea root diseases are peculiar to the tea plant. All the commoner root diseases of tea attack the trees and shrubs in the neighbouring jungle.

Mycorrhiza or Fungus Roots.

Not all the fungi which attack tea roots are the cause of root disease. The small cream coloured rootlets are normally infected by fungi which seem to do no damage and may indeed be beneficial. Roots invaded by such fungi are called mycorrhiza (Fungus Roots).

In the Darjeeling district a species of *Rhizoctonia* is commonly present in tea mycorrhiza (see mycological notes).

CHAPTER 2.

THE EXAMINATION OF THE ROOTS OF DEAD BUSHES.

The following notes may help the planter to diagnose the most common root diseases.

As soon as possible after death, the bush should be dug up. The roots should be washed with water. The bark of a healthy tea root has a dark red colour when wet.

The external appearance of a diseased root assists in the identification of the disease concerned.

1. With small white, turning black, cushions—Charcoal stump rot, *Ustulina zonata.*
2. With small black cushions, giving a sooty appearance—*Diplodia* spp.
3. With small cushions of yellowish brown mycelium—*Poria hypobrunnea.*
4. Covered with tough, thick cords or bands of white mycelium—*Fomes lucidus.*
5. Covered with white or yellowish or reddish, flat tough cords or strands forming a network—*Fomes lignosus.*
6. With longitudinal cracks (on the tap root) filled with mycelium, thick, black cords of mycelium on the exterior of the roots—*Armillaria mellea.*

7. With cords of loose, cobwebby, black mycelium over the surface—*Rosellinia* spp.
8. Covered with a loose stocking of dark grey mycelium—Black root rot, *Rosellinia arcuata.*
9. Rough with soil, stones etc., encrusted to it by cream to brown mycelium—Brown root rot, *Fomes lamaoensis.*
10. Rough with soil, stones etc., encrusted to it by red and white or black and white cords or sheets of mycelium—*Poria hypolateritia.*
11. With a velvety pad of purplish-brown mycelium on the stem immediately above the soil level and purplish-brown, branched cords of mycelium on the roots—*Helicobasidium compactum.*
12. Covered with black thorns, surface raised where the thorns appear—*Aglaospora* sp.
13. With mauve or violet tint and often waterlogged appearance—Violet root rot, *Sphaerostilbe repens.*

If the bark be peeled off carefully there are other indications—

1. White delicate fans of mycelium—Charcoal stump rot, *Ustulina zonata.*
2. White delicate fans of mycelium as in *Ustulina zonata*—*Kretzschmaria micropus.*
3. Small white (changing to black) stars of mycelium—Black root rot, *Rosellinia arcuata.*
4. White or orange (changing to mauve and finally to dark purple) strands of mycelium—Violet root rot, *Sphaerostilbe repens.*
5. Dotted with numerous, small, black dots—*Rhizoctonia bataticola.*
6. Thick, white layer of mycelium with a mushroom smell—*Armillaria mellea.*

7. Small scattered patches of brownish-white mycelium—*Fomes applanatus.*
8. Patches of yellowish-brown mycelium—*Poria hypobrunnea.*
9. Thin film of white mycelium—*Poria hypolateritia.*

If a longitudinal slice be cut off from the woody portion of the root the following indications are likely to be found at a later stage :—

1. Black lines running through the wood—*Ustulina zonata.*
2. Black lines as in *Ustulina zonata*—*Kretzschmaria micropus.*
3. Thin black lines as in *Ustulina zonata*—*Aglaospora* sp.
4. Black specks resembling those of *Rhizoctonia bataticola*—*Rosellinia arcuata.*
5. Numerous black specks—*Rhizoctonia bataticola.*
6. Small scattered patches of white mycelium—*Fomes applanatus.*
7. Wood, darker in colour, containing cavities filled with white mycelium—*Fomes lucidus.*
8. Rotted portions of wood have hard brown lines with cream coloured soft wood in between, finally giving a honeycomb-like structure—*Fomes lamaoensis.*
9. Reticulations of light brown, thin lines—*Hypoxylon asarcodes.*
10. Small sheets of yellowish-brown mycelium—*Poria hypobrunnea.*
11. Wood slightly pink or pinkish-brown when dry—*Helicobasidium compactum.*
12. Bluish-black colouration of the wood—*Diplodia* spp.

Bushes attacked by primary root diseases, such as Charcoal stump rot, Brown root rot and Red root rot, usually die suddenly and more frequently occur in patches.

Bushes attacked by secondary root diseases such as Violet root rot more commonly die gradually and show less tendency to occur in patches. It is desirable to send representative specimens to Tocklai for examination and the following notes on selecting and sending such specimens will be useful.

How to send specimens of Root Diseases for identification.

Selection of specimens.—(*a*) Where a number of bushes have died in a patch care should be taken to select one bush which is typical of the remainder. If there is more than one patch a bush should be selected from each. (*b*) Where the deaths have not occurred in patches, a number should be dug up and two or three of these taken at random for despatch. The exact position whence each of the bushes was taken should be written down at the time. (*c*) Shake off the soil adhering to the roots and rinse them with water but do not scrub.

Dividing the specimen bush.—In most cases it is possible to divide the selected bush into two halves by a vertical saw cut. Care should be taken to arrange the position of the cut so that each half is typical of the other.

Labelling.—The two halves should be labelled by cutting or stamping the same letter or number on the cut surface of each. The label giving the name of the garden should be attached to one half.

Packing.—The half which is labelled with the name of the garden should be wrapped up in gunny and despatched to the Director at Tocklai. The other half should be put away carefully pending the receipt of a report on the specimen sent to Tocklai.

Information required.—The following schedule will give the manager an idea of the information that is likely to be relevant.

Points on which information is desirable :—

(1) Company.

(2) Estate.

(3) Section.

(4) Age of tea.

(5) Jat of tea.

(6) Description of soil :—

(*a*) Light or heavy.

(*b*) Hard or easy to cultivate.

(*c*) Liable to form a surface pan or otherwise.

(*d*) Colour.

(*e*) Other characteristics if any.

(7) Drainage :—

(*a*) Is the soil well above water level in the rains?

(*b*) Is the water level low in the cold weather?

(*c*) Is the section on sloping or level ground or a teelah?

(*d*) If on sloping ground is it adequately protected from wash?

(*e*) How is the section drained *i.e.* are the drains parallel to each other running at right angles into a main drain which follows the natural fall of the land, or is there a contour system of drainage?

(*f*) How far are the drains apart?

(*g*) How deep and wide?

(8) Shade :—

(*a*) Is the tea shaded by trees or shrubs?

(*b*) Are these free from blight, canker or root rot?

(9)

Year.	Pruning.		Manuring.			Pests & Blights.			Yield.
	Type.	Date.	Manure used.	Quantity per acre.	Date of application.	Name.	Severity.	Time of attack.	
	For previous ten years.								

Plate 1. Charcoal stump rot (*Ustulina zonata*, Lev., Sacc.). Tea stump showing (a) the black crust (charcoal-like when broken) immediately above the collar, occasionally on exposed roots; (b) the white fan-like felt of mycelium on the surface of the wood beneath the bark, (this is produced wherever the fungus attacks the wood) and (c) black line at the edge of the fan.

(10) If the area is a replanted one the yield of the area prior to replanting will also be helpful.

(11) The approximate number of bushes affected.

(12) Does the trouble occur in patches of bushes or scattered over the area?

(13) If there is any stem disease, is it confined to any particular side of the bush?

(14) Have there been any exceptional climatic conditions such as hail, drought, flooding, etc., likely to have influenced the bushes concerned?

(15) What is the manager's opinion of the cause of the trouble? (This is particularly valuable in the case of young tea).

CHAPTER 3.

ROOT DISEASES IN WHICH A FUNGUS PARASITE IS THE PRINCIPAL CAUSE.

Some root diseases are definitely caused by parasitic fungi. The fungus is the primary cause of the disease and even the most vigorous bushes may succumb to attacks. These may be termed primary root diseases.

Two Common Primary Root Diseases.

Charcoal stump rot, *Ustulina zonata* (Lev.) Sacc.—This disease is more frequent on sandy soil than on clay but it is not unknown on stiff silty soil.

Bushes attacked by this disease usually present an unhealthy appearance for a week or two before their death. Death comes suddenly often during wet weather.

The external appearance of the diseased root is not characteristic—a few black spots are sometimes seen scattered here and there. These are agglomerations of the fungal threads which have emerged from inside of the bush and failed to progress further to form fructifications

on account of their being situated underground. The fungus grows most freely between the bark and the wood and if the bark be removed the wood will be found covered with beautiful delicate white fan-shaped patches of mycelium which extend into the live portions of the tissues. As the disease progresses the extreme edges of these fans sometimes become black. Irregular black lines are seen penetrating the wood of the root when it is cut. It should be noted however that other fungi also form black lines in the wood of tea bushes so that these lines cannot be regarded as peculiar to this disease. The fine fan-like plates of white mycelium which spread over the wood differ in appearance from those produced by other root fungi of tea and may be considered characteristic of the disease.

The disease spreads from root to root by contact. The fungus does not spread free through the soil. In exceptional cases tea may be infected by spores through dead snags above ground. In the latter case it is more usual for a portion of the bush concerned to die suddenly.

Brown root rot, *Fomes lamaoensis*, Murr.,—*Hymenochaete noxia* (Berk).—As a general rule the first intimation of an attack of this disease is the sudden death of two or three bushes adjoining one another. Sometimes as many as twenty will die out within a week. The most characteristic feature of this fungus is the presence of a crust of sand on the diseased roots. This crust is held together by a felt of brown mycelium which becomes darker with age. This crust may extend up the stem above ground level for several inches. This may have taken many days to develop. If the bark of the root be removed there may be seen a thin layer of white or brownish mycelium between it and the wood. Unless the disease is in its early stage the wood will be seen to be marked with thin russet-brown lines which anastomose frequently. The wood may not exhibit much evidence of decay in the early stages but in old cases the tissues within these dark lines decay leaving a honeycomb structure, the bounding lines being dark and hard while the intervening rotting portion is yellow and soft. The fungus first of all attacks the bark cells and spreads from these to the wood and pith.

Plate 2. Brown root rot (*Fomes lamaoensis*, Murr). Tea root encrusted with sand, soil and stones held to the roots by a brown felt of fungus; (a) the brown felt of fungus (this often appears on the main stem immediately above the soil surface).

As the fructification is very rare spores play little part in infection and their agency may be ignored. In many cases the infection can be traced along a root to a decaying tree stump. Fence posts, bridges, in fact any kind of dead wood, may form a centre of infection. The fungus does not spread through the soil, nor does it appear to live in the soil apart from dead wood. On dead wood it may live for very many years and any tea root growing in contact with the diseased wood becomes infected. For instance, at Tocklai an outbreak of this disease on five years old tea was traced to a piece of Nahor (*Mesua ferrea*) root which must have been buried in the soil four feet deep for at least fourteen years. Similar observations have been recorded from Ceylon also.

The disease is always more prevalent on sandy soils which have recently been opened out from virgin forest. The older forests of Assam wherever they are growing on sandy soil are badly infected. The death of a few bushes is usually a forerunner of many deaths at the same place. Ring after ring of plants die out and if the disease be not checked acres of tea may be destroyed in a few years. In some cases the writer has seen as much as twenty acres of tea killed out in one patch. Fortunately the disease does not spread very rapidly from bush to bush; but as it generally takes some months for an infected bush to die, a considerable number of plants in the neighbourhood of the dead bush may be infected and be spreading infection for a long time before the presence of the disease is suspected. The disease usually attacks well-grown bushes, but there are instances of young plants also being attacked. In one case thousands of plants died in one year on a young clearance.

The Treatment of Primary Root Diseases.

Isolation trench no longer recommended.—More than fifty years ago the foresters in Europe sought to prevent root disease spreading by encircling the diseased trees with shallow trenches. This method was adopted in the case of rubber, tea and coffee. In North East India we recommended that a trench be dug deep enough to prevent the roots of bushes on opposite sides from growing into

contact. It was further suggested that a complete ring of apparently healthy bushes be enclosed within the trench. Observations on the progress of such diseases showed that a bush may be infected for many years before it dies or even shows obvious signs of sickness. The trench is often filled in long before the danger of a further extension of the disease is past. In certain cases the digging of an isolating trench is still recommended but it is usually unnecessary if the recommendations given below are carried out carefully.

Soil disinfection not recommended.—The application of quicklime to the soil whence a diseased tree had been removed was also commonly made in Europe. Research work on the fungi concerned showed that an alkaline medium was unfavourable to their growth. An improvement on the addition of lime alone was made in Java. By watering the limed soil with sulphate of ammonia free ammonia gas was set free in the soil. The application of Iron sulphate, Zinc sulphate and Copper sulphate solutions was also advocated. All of these chemical treatments would hinder the growth of the fungus mycelium wherever they came into contact with it. Observations extending over many years have failed to show that the mycelium of these fungi is capable of extending through the soil except in or near pieces of dead wood or collections of rotting vegetable matter. As chemicals applied to the soil are not likely to penetrate pieces of dead wood, their value in preventing the spread of the root disease fungus is doubtful and such applications are no longer recommended in North East India.

The removal of infected material, the only reliable treatment.—It has been found that the careful removal of all dead wood from the soil in the vicinity of the diseased bushes is sufficient to prevent further extension of the disease concerned. As a further safeguard it is recommended that wherever diseased roots are found to be very close to the roots of a neighbouring apparently healthy bush the latter should be removed. Where an apparently healthy root of a shade tree or jungle tree is found to be close to the diseased root it should be traced out for 3 or 4 feet in each direction and

removed. The cut end attached to the tree should be washed with an antiseptic such as Lime sulphur solution and painted with Bitumen paint before it is covered up with soil. Should the root of the shade or jungle tree appear to be diseased, the diseased portion should be traced right out and removed including 3 or 4 feet of apparently healthy root. The cut end attached to the living tree should be treated as described above. The roots and other wood removed from the soil should be burned. If all the infected material be removed in this way no further trouble is likely to be experienced and no other precautions are necessary. Good supervision is however essential to the proper carrying out of such work.

Prevention of Primary Root Diseases.

Tree stumps and other dead wood.—Most of the primary root diseases may be traced to decaying wood. Very frequently the remains of a tree stump are the centre of infection but it is not unusual to find wooden fence posts and wooden bridges acting in the same way. Where it is necessary to have wooden fence posts a small drain should be kept between the tea and the fence. In the case of wooden bridges it is sometimes possible to protect the tea bushes in a similar way.

Although the stumps of shade trees are liable to become centres of infection only a very small percentage do so. The expense of removing all such stumps is therefore not justified. Where a shade tree stump is in the vicinity of tea bushes infected by a primary root disease it should be removed and its roots traced out with special care. When shade trees are thinned out it will suffice if they are cut sufficiently low for the stump to remain covered by the soil. If this be done the danger of the stump becoming infected by root disease producing fungi is much reduced as the cut surfaces will not be exposed to wind-borne spores. Soft-wooded trees usually decay rapidly and the chances of their becoming centres of infection are consequently reduced. Hard-wooded trees, such as Nahor (*Mesua ferrea*) Sal (*Shorea robusta*) and Khair (*Acacia catechu*) take much longer to decay and in practice it is found that outbreaks of primary root disease

are more frequently traced to such roots. It is therefore worth while to dig out the roots of a hard-wooded tree with special care.

Always have a dead bush dug out as soon as possible after death. If condition of the roots suggests that death was caused by a primary root disease the precautions in regard to the removal of all dead wood etc., should be observed. Otherwise the removal of the bulk of the dead roots will suffice.

PRECAUTIONS TO BE TAKEN WHEN CLEARING OLD TEA AREAS FOR REPLANTING.—Mark off any areas where patches of vacancies or of infills occur. These areas should be well defined by a temporary ditch or a bund. All the roots of both tea and shade trees should be dug right out from these areas and burned. The remaining bushes may be dug out without taking any special care to remove all the roots. The ditch or bund which defined the suspected areas may be retained for a few years after replanting has been done so that special attention may be paid to the new plants on these areas. It is unlikely that young plants will die from primary root disease until they are about 6 years old.

PRECAUTIONS TO BE TAKEN WHEN INFILLING VACANCIES.—It occasionally happens that a dead bush is overlooked until the frame has rotted away leaving no sign of the rotting roots below. It is therefore desirable to dig a fair sized hole and trace out any decaying wood which may be present before any vacancy is infilled.

CHAPTER 4.

ROOT DISEASES IN WHICH FUNGI ARE SECONDARY.

Some of the fungi associated with disease of the roots are commonly present in the tea soils of North East India. It is obvious that such fungi only attack plants which have been rendered susceptible by other influences. *Sphaerostilbe repens*, *Diplodia* sp., and *Rhizoctonia* sp., are examples of these fungi. The last named functions as a mycorrhizal fungus in the hill districts but is able to cause

Plate 3. Violet root rot (*Spherostilbe regens*, B & Br.). Tea stump showing, (a) thick mycelial strands on the surface of the wood beneath the bark (at the collar). The wood is mauve colour and the strands are white or pale orange when young, turning dark purple with age.

damage to tea plants should they become weak. There are also a number of wood destroying fungi which attack tea roots which have died as a result of damage to the branches. These fungi merely attack dead wood. The above may be classed as secondary root diseases.

Two Common Secondary Root Diseases.

Violet root rot, *Sphaerostilbe repens*, B & Br.,—This is one of the commonest fungi present in any soil in North East India. A tea bush attacked by this disease when dug up usually presents a waterlogging appearance. By washing the roots carefully the bark is seen to be dark coloured and in the later stages covered with pinkish or orange coloured pins with white heads. The roots have a peculiar odour, a vinegar-like smell. If the bark on one of the dark roots be peeled off, thick strands of fungus mycelium will be seen on the surface of the wood spreading in all directions. These are at first white, then orange, then mauve and finally dark purple. The surface of the wood of the roots as well as the inside in most cases, is mauve or violet. Frequently the wood of the roots appear to be sodden while they are still alive.

The pinkish or orange pin heads mentioned above are one of the two kinds of fructifications. The other kind consists of clusters of black, minute flower-bud like structures. These are at first red but soon change to black. They are bottles full of sacs containing spores. These clusters usually form at the collar or a little above it, occasionally at the base of the branches. Sometimes they are also produced on exposed portions of root below the collar. The pin-like fructifications are only produced on the roots. They are composed of mycelial threads running together to form a stalk on the end of which the threads branch. A free type of spores is produced on the end of these branches giving the head of the stalks its white appearance. These stalks shrivel up as soon as the roots became dry.

Roots of tea bushes attacked by this disease, even when covered with mycelial strands, remain alive for a considerable time and our experience shows that in many cases the bushes concerned can be nursed back to health and vigour by ameliorating conditions of growth.

Roots of vigorous jack fruit trees in the neighbourhood of Tocklai have been found to be heavily infected by this fungus.

Our experience has shown that this disease is usually associated with badly aerated, stiff soils but it is by no means confined to these. Although bad aeration is generally attributed to improper drainage it need not necessarily be so in every case. Often it is due to the physical conditions of the soil. On some sections, where the soil is exceptionally sticky, one occasionally sees a single line of good plants along the edge of each drain and all the bushes between in a very poor condition and most of them severely attacked by Violet root rot. Sometimes when a drain has been deepened and the sticky subsoil allowed to remain for some time round the collars of the adjoining bushes the latter become severely attacked by Violet root rot. If this subsoil be removed in time the diseased bushes may recover. In both these instances the condition of the diseased bushes concerned is obviously not due to lack of drains but to lack of aeration of the soil round their roots. This lack of aeration is often accompanied by a low acidity, when the condition is suspected to be due to the presence of soluble alkalis. The adjustment of the acidity may, by improving the permeability of the soil, lead to better aeration and amelioration of the condition of the tea bushes growing thereon.

Even under favourable soil conditions undue reduction in the effective leaf area may lead to such reduction in the energy absorbed that insufficient is available for the maintenance of the whole of the branch and root system of the bush. The moribund portions then become susceptible to the attacks of parasites which are unable to attack vigorously growing tissues.

Consideration of the above will indicate the lines on which treatment of bushes affected by Violet root rot should be undertaken. These may be summarised as follows :—

1. Allow more growth to remain on the bushes.
2. Improve the physical condition of the soil by adjusting its permeability and increasing drainage where necessary.

Plate 4. Violet root rot (*Sphaerostilbe repens*, B. & Br.). (a) clusters of black perithecia on a tea stem near the soil surface (these are often produced at or near the collar or on exposed roots); (b) strands on the surface of the wood beneath the bark (these are white or pale orange when young, turning dark purple with age).

DIPLODIA DISEASE = INTERNAL ROOT DISEASE = *Botryodiplodia theobromae*, PAT. = *Thyridaria tarda*, BANC.—This is one of the commonest fungi in the soils of North East India. It is not strictly speaking, a root disease of tea as it attacks also the other parts of the plant not excluding the leaves.

Tea roots attacked by this fungus, when dug up and washed, do not present any external evidence of the disease. They appear to be quite normal except in very old cases, when the roots are often covered with small, black cushions, giving them a sooty appearance. Unlike other root diseases it does not produce any strands, fans or films of mycelium either on the bark or between the bark and the wood. The only symptom to be noticed on removing the bark of a badly diseased root is discoloured streaks in the wood which resemble the effect produced by dipping wood into blue-black ink and allowing it to dry.

The common kind of fructification is small black spheres (*pycnidia*) usually embedded in the bark of dead stems and roots which otherwise are normal in appearance. Sometimes these spheres are produced in clusters which appear as black cushions on the exterior of the bark. In some cases these cushions are hairy owing to the growth of hyphae on the top of the spherical bodies. If the bark be shaved lightly with the knife the pycnidial cavities appear as minute white dots surrounded by black rings. Sometimes, on bushes growing on heavy stiff soil, the black spots on the bark which mark the position of the pycnidia, are fringed with a white chalky powder. This is due to another fungus which does not attack the bush but grows at the expense of the *Diplodia* fungus.

Most dead twigs and roots, especially in a sandy soil, become infected by this fungus very soon after death. The presence of this fungus in a dead root or branch is no proof that it has caused or hastened the death of the root or branch concerned. Experience has shown that the fungus may live for a considerable time in the wood without causing any apparent damage to the plant. It has also been observed that weak bushes, attacked by this fungus, when helped by judicious manuring and resting, are capable of throwing off the disease.

Susceptibility to this disease is almost always associated with lack of reserves (starch). Young plants in particular are liable to infection when depleted of reserves on account of defoliation due to drought, Red spider etc.

Soil conditions are not so closely related to susceptibility to *Diplodia* sp., as they are in the case of Violet root rot. *Diplodia* has occasionally been observed to attack bushes growing on coarse sandy soils with a high pH value although the roots of the bushes concerned are well stocked with starch reserves.

THE TREATMENT AND PREVENTION OF SECONDARY ROOT DISEASES.

In the case of root disease associated with fungi which are normally present in the tea soils it is obvious that the fungus concerned is not the only prime cause of the ill health of the diseased bushes. There must be factors which have rendered the bushes especially susceptible to the attacks of such fungi. Any combination of factors which tends to render the plant less vigorous is liable to increase susceptibility to disease of this kind. It does not follow that the same factor or combination of factors is operative in all bushes affected by a specific secondary root disease.

RESERVES OF ENERGY.—One of the principal factors governing the vigour of a tea bush is the energy supply. Most, if not all, of the energy required by a green plant is obtained by the absorption of light by the green portions. The effective energy-absorbing area is conditioned by the plucking and pruning which the plant undergoes. The leaf area may be further reduced by the ravages of pests and blights.

The following simple test, carried out in the cold weather, will indicate whether the bushes growing on a particular area are deficient in energy reserves. A healthy lateral root, about half an inch in diameter, should be taken from each of about a dozen bushes taken at random. The end of each root should be cut smooth with a sharp knife and treated with a weak solution of iodine. If the cut surface goes a deep purplish-black all over, it means that the root is well filled with starch. Starch is one of the most important reserves con-

taining energy. If the cut surface does not go black all over at the time of the year in question lack of energy reserve is suggested. During the growing season the amount of starch fluctuates considerably. It is less at the end of a flushing period and more at the end of a banjhi period. During the dormant season the starch remains more or less constant and the relative amount present in the roots at that time may be taken to be representative of the energy reserves of the bush concerned.

MANURING.—The work of the chemical section has shown that the most important chemical substance which the tea plant requires is nitrogen in a form available for its use. Nitrogen stimulates the growth of new leaf and thus increases the energy absorbing area. If however all the extra leaf induced by the manuring be removed the balance of energy absorbed may be affected adversely. Energy is required for the production of new growth and the latter does not absorb any surplus of energy until it has reached full growth *i.e.* until some time after it has reached the stage suitable for plucking. At the same time manuring with nitrogen, if sufficiently heavy, also tends to increase the leaf area below the plucking level. Thus the application of nitrogenous manures is likely to assist tea bushes to maintain their vigour and in consequence to resist the attacks of secondary root diseases. The effect on the vigour of the tea plant produced by suitable manuring may be enhanced by temporarily reducing the amount of leaf removed. This may be done by raising the plucking level or in some circumstances by allowing the bushes to remain unplucked for a portion of the growing season. No general rules can be made in regard to the resting of tea plants. Each case requires to be considered on its merits.

THE PHYSICAL CONDITION OF THE SOIL.—Root disease of the secondary type is usually more prevalent on bushes growing under unsatisfactory soil conditions. This is not because the soil conditions are more suitable for the growth of the fungus concerned but on account of their effect on the growth of the tea plant. When a tea plant is growing under unsatisfactory conditions there is a greater tendency for

the effective leaf area to be limited and the effects of undue reduction of leaf area by overplucking, Red spider etc., are more rapidly apparent. The most common soil defect indirectly associated with secondary root disease is lack of aeration. It is more frequently due to the nature of the soil than to the lack of drains. This is often illustrated by lines of poor bushes bordering drains, on which poor subsoil has been spread. Much can be done to improve the physical condition of such soils by judicious manuring.

APPENDIX.

MYCOLOGICAL NOTES.

Ascomycetes.

Charcoal stump rot, *Ustulina zonata*, (Lev.), Sacc.—A primary disease. Common over all the tea districts of North East India. Occurs on both sandy and clay soils, mostly on the former.

Black root rot, *Rosellinia arcuata*, Petch.—A primary disease principally on gardens in the hill districts. Present also in the plains. It seems to cause most damage on stiffer soils especially under excessive shade.

Violet root rot, *Sphaerostilbe repens*, B. & Br.—A secondary disease. Common in all the tea districts of North East India on any soil. Most prevalent on badly aerated soil. Only bushes weakened by adverse conditions of growth are damaged by this disease.

Kretzschmaria micropus (Fr.) Sacc.—A primary disease of rare occurrence. It is probably an abnormal form of Charcoal stump rot, *Ustulina zonata*.

Hypoxylon asarcodes, (Theiss) Mill.—A primary disease of rare occurrence. So far this disease has been reported on only a few specimens from Jalpaiguri district and on one from the Assam Valley.

Aglaospora sp.—Probably a secondary disease. So far only about a dozen specimens of this disease have been received from Jalpaiguri district and one from Upper Assam. It seems to spread from a decaying branch to the roots. It is distinct from *Aglaospora aculeata*, Petch.

Diplodia sp., *Botryodiplodia Theobromae*, Pat—*Thyridaria tarda*, Banc. —A secondary disease. The commonest of all the tea fungi so far investigated in North East India. Present everywhere on any kind of soil or dead wood. Only bushes weakened by other causes are damaged by this disease.

Ascomycetae.

Ustulina zonata, (Lev.), Sacc.—Stroma effused, concentrically furrowed, rarely develops a stalk, often undulated, about 3 m.m. thick and about 8 c.m. in diameter, at first white, when it bears conidia on its surface on

simple, thickly crowded conidiophores; changes to greenish grey, is dotted with openings (ostioles), finally changes to charcoal black when it is hard and brittle.

Conidia hyaline, continuous, narrow oval, .004—.008 m.m. by .002—.003 m.m.

Perithecia spherical or oblong, immersed, mouths scarcely projecting, about 1 m.m. in diameter. Asci cylindrical, 8 spored, about .25 by .01 m.m. Paraphyses present. Ascospores opaque, black-brown, boat-shaped, uniseptate, ends obtuse, .027—.038 m.m. by .007—.013 m.m.

Rosellinia arcuata (Petch).—Conidiospores are produced on short, bristle-like stalks which occur in clusters on the sheet of mycelium giving it a velvety appearance. The stalks are branched above and at the end of each branch the conidia are produced. Conidia one celled, narrow oval, hyaline, about .004—.006 m.m. by .002 m.m.

Perithecia spherical, black, superficial, look like grains of shot, grow side by side to form clusters on the grey stocking of mycelia at the base of the stem, about 2.5 m.m. in diameter. Asci cylindrical, about .26 to .35 m.m. by .007 to .009 m.m., eight spored, spores uniseriate. Paraphyses long, thread-like, about .002 m.m. across. Ascospores one celled, black, boat-shaped, with pointed ends, about .04—.047 m.m. by .005—.007 m.m.

Sphaerostilbe repens (B. & Br.).—Conidiospores are produced on short red stalks surmounted by a white head. These stalks about 2-8 m.m. long consist of elongated hyphae growing side by side to form a solid mass. They are hairy due to the growth of laterally projected hair-like processes. The white knob at the end is composed of branched hyphae resembling a brush. The conidia are produced singly at the end of each branch. They are oval, hyaline, one celled, about .011 to .013 m.m. by .004 to .0055 m.m.

In culture two kinds of conidia are produced on ordinary hyphae. No stalks are formed. One kind is round, brown, thick walled, about .01 to .012 m.m. in diameter, the other oval, hyaline, thin walled, up to .02 m.m. long by .01 m.m. broad.

Perithecia flask shaped, at first red changing to black, crowded, about .6 m.m. by .4 m.m. Asci irregularly cylindrical, 8 spored, spores in one or two rows, about .08 m.m. by .0075 m.m. Paraphyses present. Ascospores

Plate 5. Black root rot (*Rosellinia arcuata*, Petch); (a) Groups of perithecia on tea branches near the collar (these are usually produced at the base of big branches near the soil surface); (b) star-like strands of mycelium on the surface of the wood beneath the bark (these are white when young, turning black with age).

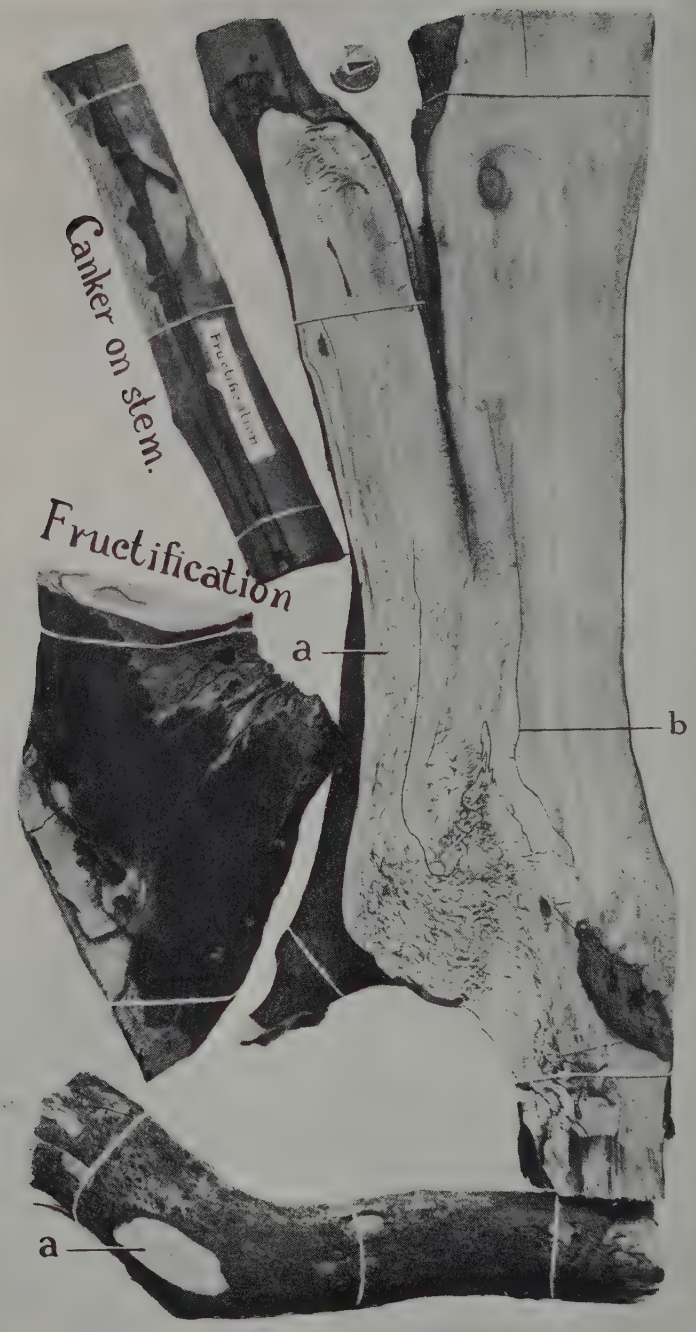

Plate 6 (*Hypoxylon asarcodes*, Theiss., Mill.). Sections of tea stump and stems and a piece of root showing formation of cankers on the stem, fructification of the fungus (this looks like a patch of dried black paint and is produced on the main stem above the collar or on the branches); (a) brown reticulations and (b) black lines in the wood.

uniseptate, slightly constricted at the septum, oval with tapering ends, purplish-brown to reddish-brown, rarely with longitudinal striations and measure about .015 by .0056 m.m.

Kretzschmaria micropus (Fr.) Sacc.—Produces black rhizomorphs which form globose heads at their ends. In other respects it resembles *Ustulina zonata*. Both fungi have similar spores.

Sharples has produced the *Kretzschmaria* form in pure culture from *Ustulina* and states that the latter sometimes forms rhizomorphs in culture.

Hypoxylon asarcodes (Theiss) Mill.—Stroma effused, hard, carbonaceous, crustose, about 1 m.m. thick, at first appearing as thin, slightly raised, deep black spots of wound paint on the surface of the stem from the ground level upwards to about 13 inches.

Asci cylindric, 8 spored. Paraphyses present. Ascospores dark, continuous, tapering towards the ends, occasionally boat shaped, .0072 to .0108 m.m. by .0036 to .0055 m.m.; average .0088 m.m. by .0045 m.m.

Aglaospora sp.—Perithecia immersed in the cortex in a carbonaceous stroma. They occur on the stem just above the ground level as well as on the roots, either singly or in groups, occasionally with a common ostiole; measure up to about 1 by 1.5 m.m. Ostioles conical, tapering almost to a point, projecting about 1.5 m.m. above the surface. Asci fusoid, flattened on top with a distinct canal just beneath, and a short tapering stalk, 8 spored, about .17 to .209 m.m. by .0235 m.m. Ascospores fasciculate, unicellular, curved, subhyaline, cylindrical and tapering towards one end, about .1 to .154 m.m. by .007 to .009 m.m.

Diplodia sp. = *Botryodiplodia Theobromae*, Pat. = *Thyridaria tarda*, Banc. —The common kind of fructification is black spherical bodies (pycnidia) either half embedded in the bark or produced in clusters in a stroma on the exterior of the bark. The pycnidia are globose or sub-globose, ostiolate and dark brown to black in colour. In some cases the pycnidia are covered with hairs. The pycnospores are oval or ovoid, densely granular, often very thick walled. They are at first hyaline and continuous but afterwards they are of a yellowish-brown tinge and ultimately become dark brown in colour and uniseptate. The dark brown uniseptate spores have longitudinal striations. They measure .0295 m.m. by .01475 m.m. The spores are borne on short conidiophores

and are liberated in threads through the ostiole of the pycnidium. These spore threads are at first white but afterwards become black. Paraphyses are present.

The other form of fructification, the perfect stage of the fungus, is found on the stem and exposed portion of the root. It is very uncommon. It has so far only been found on four occasions. The perithecia are immersed with the mouth projecting. The asci are cylindric-clavate either sessile or with a very short stalk and contain 8 spores. The ascospores are arranged in irregular rows, they are oblong, triseptate, slightly constricted at the septa and of dark brown colour. The asci measure from .115 to .15 m.m. by .018 to .0265 m.m.; the ascospores measure from .026 to .0265 m.m. by .0064 to .009 m.m., and the paraphyses are .13 to .45 m.m. in length.

BASIDIOMYCETES.

Rhizoctonia bataticola (Taub).—A secondary disease. Very common on any soil in North East India. It has been observed to cause damage only to bushes previously weakened by adverse conditions of growth.

Rhizoctonia spp.—These are very commonly present on dead tea roots but there is no reason to suppose that they have caused the death of the roots in question. In Darjeeling district a species of *Rhizoctonia* is commonly associated with a type of mycorrhiza not found in other tea districts. In this the primary cortex remains alive for months after the cork cambium has formed. The cells are enlarged and are filled with fungus mycelium. These mycelia completely disappear from the cells before they dry up and disintegrate. Mycorrhiza of this type have a stringy appearance while normal roots of the same age are wiry. Occasionally on bushes which are growing under adverse conditions the *Rhizoctonia* fungus has been observed to penetrate the tissues beyond the cortical cells. It is possible that it then functions as a weak parasite.

Armillaria mellea (Vahl).—A primary disease. Not common on tea in North East India.

Auricularia auricula-judae (L) Schr.—One of the secondary diseases commonly found on dead larger snags from which it spreads to the roots.

Fomes applanatus (Pers).—A secondary disease. One of the commonest bracket fungi on decaying stumps. Very rarely found on living tea bushes.

Plate 7. (*Aglaospora sp.*). Tea root showing (a) groups of perithecia with horn-like necks (these are produced on the roots and often on the stems near the soil surface).

Brown root rot=*Fomes lamaoensis*, (Murr).=*Hymenochaete noxia* (Berk).—A primary disease. Common over all the tea districts of North East India. It is more prevalent on sandy soils than on clay ones.

Fomes lignosus (Klotzsch).—A secondary disease. Seems to originate in decaying stems and thence spreads down to the roots. Of rare occurrence on tea roots but common on dead wood in the jungle.

Fomes lucidus (Leys) Fr.—Probably a primary disease but not common on tea. Frequently found on jungle tree stumps.

Helicobasidium compactum (Boedijn).—A primary disease of rare occurrence. It seems to cause damage only to young plants below 5 years of age Very rarely attacks mature bushes.

Irpex destruens (Petch).—
Irpex subvinosus (B. & Br.).—
Polyporus interruptus (B. & Br.).—
Polyporus mesotalpae (Lloyd.).—
} These diseases are probably secondary. Only one or two specimens of each have been found on tea in North East India.

Poria hypobrunnea (Petch).—A secondary disease. It is the commonest fungus attacking stems after they have been killed by other things. It spreads down to the roots causing the affected parts to rot and decay. It does not develop any external mycelium on the stems but occasionally forms small cushions of yellowish-brown mycelium on the roots.

If the bark is peeled off thin films of yellow mycelium are found. In old cases such films or cushions develop inside the wood which is soft and rotten.

The fructification of the fungus is a yellowish to fawn coloured incrustation formed mostly on the underside of big branches. The colour of the crust becomes dull brown or grey with age. It has never been found to attack healthy living tissues.

Red root rot, *Poria hypolateritia*, (Berk).—A primary disease. Not so common as Brown root rot or Charcoal stump rot, although specimens of this disease have been received occasionally from all the tea growing districts.

Basidiomycetae.

Auricularia auricula-judae (L) Schr.—Bracket-shaped, brown, resembling human ears, soft, gelatinous about 1.5 to 8 c.m. across, occur on the stem just above the ground level or higher up.

Fomes lamaoensis, Murr = *Hymenochaete noxia*, Berk.—The fungus rarely fruits in North East India. The writer has found only three specimens of the fruit body (immature) on tea so far. The fructification is a brown plate of mycelium adhering to the collar just above the soil. Another immature fruit body formed on a piece of gunny bag in which a diseased bush had been packed. Mature fruits of this fungus have been found on decaying logs in contact with tea bushes which have died of Brown root rot and the appearance of the fungus in the decaying jungle wood was identical. Petch describes the fructification of this fungus in the following terms :—

"It is bracket-shaped, often irregular and consisting of several brackets fused together side by side, three or four inches broad, about half an inch thick, and very hard. On the lateral roots of mango and Hevea it may form a continuous border running for several feet, on either side of the root, united by a resupinate part on the lower surface. The developing pileus is purple-brown, or almost black, with a yellow margin. When mature and dry, it is purple-brown to blackish-brown, often with concentric, narrow, blackish zones, yellow-brown towards the margin, smooth, and sometimes concentrically furrowed. The lower surface is dark brown, or almost black, often with greyish bloom. When broken in two, it is seen to consist of a thin, dark, hard outer crust, with brown, or yellow-brown tissue internally, the latter usually zoned with curved lines parallel to the margin. The lower half of the section consists of a darker layer of vertical tubes in which the spores are produced".

Fomes lignosus (Klotzsch).—Bracket-shaped, semi-circular, about 3-8 c.m. in diameter and up to 12 m.m. thick, woody, smooth with a yellow brown margin, red brown with concentric dark brown lines, concentrically grooved or furrowed, radially striated, silky. Lower surface deep orange changing to red brown with age.

Fomes lucidus (Leys) Fr.—Bracket-shaped, sometimes stalked, from half an inch to 3 or 4 inches thick and from 2 inches to as much as 2 feet in diameter on large trees. Upper surface smooth, yellowish-red to deep red, shining, lacquered, concentrically zoned. Immature brackets are white and swollen at the edges, the colour gradually deepens until it assumes the same shade as the rest of the upper surface.

Plate 8. (*Helicobasidium compactum*, Boedijn). Tea root showing (a) the purple-brown pads of mycelium (these are always produced on the stem above the soil surface); (b) purple-brown mycelial threads running along the surface of the roots.

Helicobasidium compactum (Boedijn).—Boedijn and Steinman give the following descriptions :—

"The hyphae are brown, branched, and septate, thin-walled, and .005—.0075 m.m. broad. They chiefly run vertically with the substratum. On the periphery a number of hyphae bend, taking a more horizontal direction. From these hyphae the hymenial elements arise. They are colourless, of the same thickness as the brown hyphae, while the whole layer measures about .1—.125 m.m. These colourless threads are strongly twisted and bent, branching profusely near the periphery. The last branches furnish the true basidia.

These are straight at first, afterwards bent, and provided with 1—3 cross-walls, .028—.04 m.m. long, .005—.008 m.m. broad. From each basidium cell a long sterigma may originate, on which the spores are formed, usually only two spores per basidium. The sterigmata have a length up to .025 m.m., and a thickness of .001—.002 m.m. The spores are colourless, one-celled, long pear-shaped, the narrow pole terminating in a blunt point, sometimes being slightly bent, the other pole broadly rounded. Length .012—.02 m.m. (some spores up to .032 m.m.), breadth .004—.0055 m.m."

Poria hypolateritia (Berk).—The fungus, like *Fomes lamaoensis*, very rarely produces fructifications on tea in North East India. Petch describes the fructifications as—"Effused, pinkish or pale red with a white tomentose margin at first. Internally white, the extreme basal layer red or red-brown, horny. Pores medium up to 0.2 m.m. diameter, angular, dissepiments thin. Total thickness about 1 m.m.".

Poria hypobrunnea (Petch).—Crustose, effused, yellowish to fawn coloured changing to dull brown or grey, corky. The crust, about 1.5 m.m. thick and up to several centimeters across, is composed of closely packed tubes about 0.1 m.m. in diameter arranged at an angle to the surface.

Note.—It is customary to express .001 m.m. by the Greek letter "mu". Unfortunately the letter types are not available in Calcutta and the somewhat cumbersome method of expressing the dimensions in millimetres has been substituted.

Plate 9. Early stage of Red root rot (*Poria hypolateritia*, Berk). Tea root showing (a) the rhizomorphs of the fungus on the roots (these are white at the early stage, turning chocolate-red and finally black with age). Various species of Fomes have a similar appearance.

Plate 10. Red root rot (*Poria hypolateritia*, Berk). Tea root showing the mottled appearance of the roots and (a) the chocolate-red sheets of fungus on the surface of the bark (these turn black with age); (b) the white mycelium beneath the black sheets. Incrustation of stones, soil and sand on the roots is often associated with this disease also.

Plate 11. (*Fomes applanatus*, Pers.). Tea bush showing (a) the fructification (bracket) of the fungus at the collar. This is an example of the bracket type of fructification.